# IN-SITU MONITORING METHOD AND SYSTEM FOR MOLD DEFORMATION IN NANOIMPRINT

## FIELD OF THE INVENTION

[0001] This invention relates to nanoimprint, and more particular to a method and a system for in-situ monitoring of mold deformation in a nanoimprint process by marking on the mold and monitoring the deformation of the mark.

## BACKGROUND OF THE INVENTION

[0002] With the progress of nano-technology, more and more materials are processed at the nano or even molecular scale. Micro-contact printing, scanning probe-based technique and nanoimprint are among the most commonly used technologies.

[0003] As described above, the nanoimprint is considered the most potential to achieve manufacturing ultra large-scale integrated (ULSI) nano systems with low cost and high yield rate. The nanoimprint technology has the advantage of using a single step to transfer the same nano pattern and manufacture nano structure on a large area chip substrate with a single mold. This technology is widely used in manufacturing nano electronics, optical components, high-density storage devices, nano electromagnetic devices, biological devices, and nano electromechanical components.

[0004] However, the nanoimprint technology is yet mostly a laboratory prototype for research purposes despite its advantages and potential. A commercially viable machine is not available because the technology still faces many pending problems, including the alignment in multi-layer component manufacturing, the large size molds accompanying

high yield rate, the molds with high density patterns, mold sticking, solidification of polymer, mold life span and imprinting temperature and pressure, and the quality and the standardized verification of final products. As described above, the improvement of the yield rate is the key factor for the commercialization of nanoimprint technology.

[0005] In the nanoimprint process, it requires a high imprinting speed to achieve a high yield rate. At such a high imprinting speed, the uniformity and precision of imprinted micro and nano scale structure and components will be lost if the mold is deformed. In addition, if deformation of the mold is not caught by the production operators in time, a lot of defected products will be produced, and the yield rate suffers.

[0006] Conventional technologies use dynamic computational methods to construct theoretical prediction model of micro components in order to determine the mold deformation. Based on the prediction model, a simulation of micro deformation of the mold is obtained. However, because of the difference between the ideal boundary conditions and the real boundary conditions, the simulation is unable to provide practical information. Further more, when the automatic manufacturing process needs the online real-time mold deformation information for judgment, the simulated deformation of mold is not applicable.

## SUMMARY OF THE INVENTION

[0007] The objective of the present invention is to provide real-time accurate measurement of the mold deformation in nanoimprint, in order to develop an online real-time detection method for mold deformation based on direct quantitative measurement and observation. With this method, the mold deformation is controlled within the precision of a nano scale, in order to provide a basis for high-yield rate automatic manufacturing process.

[0008] In the nanoimprint process, the mold is deformed due to the subsequent imprinting pressure, repetitive uses, or other external factors. The deformation of the mold also causes the deformation of the marks on the mold body. Therefore, to achieve the aforementioned objective, the present invention provides a method for in-situ monitoring of mold deformation by using a database to store temporary information during the following steps: (a) providing a mark on the mold body that is easy to observe in order to monitor the mold deformation, (b) installing a signal source and a monitor device for monitoring the micro and nano deformation quantity on the mold, (c) transforming the above deformation quantity into computer signals for storing in the database and (d) issuing controlling or warning signals to the imprinting machine based on the processing results of the stored information in the database.

[0009] The present invention will become more obvious from the following descriptions when taken in connection with the accompanying drawings which show, for purposes of illustration only, a preferred embodiment in accordance with the present invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Figure 1 shows a block diagram of a mold deformation monitoring system of the present invention.

[0011] Figure 2 shows a block diagram of a first embodiment of the present invention.

[0012] Figure 3 shows a system diagram of a second embodiment of the present invention.

[0013] Figure 4 shows a system diagram of a third embodiment of the present invention.

[0014] Figure 5 shows a flowchart of mold deformation monitoring method of the present invention.

[0015] Figure 6 shows an imprinting mold with a monitoring mark according to the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] Figure 1 shows a system block diagram of the present invention. As shown in figure 1, the monitoring device 120 is installed around a mold 110 of a nanoimprint machine. The mold is marked with at least one monitoring mark 111 at appropriate location for monitoring mold deformation, and a signal source 140 is also installed around the mold 110. The signal, emitted from the signal source 140, is reflected by at least one of monitoring marks 111 on the mold 110, and received by the monitoring device 120. The signal received by the monitoring device 120 varies in accordance with the deformation quantity monitoring marks 111 on the mold 110. The monitoring device 120 transforms the signals into digital signals to personal computer 150, which processes the input digital signal, and stores the temporary information in the database 160. The signal source 140 is optical, electrical, magnetic or electromagnetic.

[0017] Figure 2 shows a block diagram of a first embodiment of the present invention. As shown in figure 2, a monitoring device 220 is installed around a mold 210 of a nanoimprint machine. The mold 210 is marked with monitoring marks 211 for monitoring mold deformation, and a light source 240 is also installed around the mold 210. The light, emitted from the light source 240, is reflected by at least one of monitoring marks 211 on the mold 210, and received by the monitoring device 220. The light received by the

monitoring device 220 varies in accordance with the deformation quantity monitoring marks 211 on the mold 210. The monitoring device 220 transforms the light into digital signals to personal computer 250, which processes the input digital signal, and stores the temporary information in the database 260. A light adjustor 230 is placed between the light source 240 and the mold 210 for adjusting the input light to the monitoring marks 211. The monitoring device 220 is an optical monitoring device.

[0018] Figure 3 shows a system diagram of a second embodiment of the present invention. As shown in figure 3, monitoring devices 320 are installed around a mold 310 of a nanoimprint machine. The mold 310 is marked with monitoring marks 311 for monitoring mold deformation, and laser sources 340 are also installed around the mold 310. The laser, emitted from the laser sources 340, is reflected by at least one of monitoring marks 311 on the mold 310, and received by the monitoring devices 320. The laser received by the monitoring device 320 varies in accordance with the deformation quantity monitoring marks 311 on the mold 310. The monitoring device 320 transforms the laser into digital signal to personal computer 350, which processes the input digital signal, and stores the temporary information in the database 360. A laser splitter 330 is placed between the laser source 340 and the mold 310 for adjusting the characteristics of the input laser to the monitoring marks 311. The monitoring marks 311 can be coated with an electroplated thin film of aluminum or other appropriate materials.

[0019] Figure 4 shows a system diagram of a third embodiment of the present invention. As shown in figure 4, CCD monitoring devices 420 are installed around a mold 410 of a nanoimprint machine. The mold is marked with monitoring marks 411 for monitoring mold deformation, and light sources 440 are also installed around the mold 410. The light,

emitted from the light sources 440, is reflected by at least one of monitoring marks 411 on the mold 410, and received by the CCD monitoring devices 420. The light received by the CCD monitoring device 420 varies in accordance with the deformation quantity monitoring marks 411 on the mold 410. The CCD monitoring devices 420 transform the light into digital signal to personal computer 450, which processes the input digital signal, and stores the temporary information in the database 460. An attenuator 430 and a reflector 435 are placed between the light source 440 and the mold 410 for adjusting the characteristics of the input light to the monitoring marks 411. The monitoring marks 411 are made of mirrors with high reflection, of which the surface is coated with an electroplated thin film of aluminum or other appropriate materials.

[0020] The present invention uses a database for storing temporary information. Figure 5 shows a flowchart of the present invention. As shown in figure 5, the method comprises the steps of: (a) providing a mold, marking the mold with at least one monitoring mark for monitoring deformation, (b) installing at least one signal source and at least one monitoring device around the mold, (c) recording a reference pattern in the database before imprinting, the reference pattern is obtained by using the signal source to emit signals to the monitor marks, and using the monitoring device to receive the interference pattern reflected from the monitoring marks, and the interference pattern is recorded as the reference pattern, (d) detecting a plurality of interference patterns during the imprinting, the interference patterns are recorded in the database, (e) comparing the interference patterns during imprinting and the reference pattern and (f) stopping or issuing warning if the comparison showing a deformation, otherwise, continuing to monitor the imprinting.

[0021] The aforementioned mold with the monitoring marks is used in mold

deformation monitoring and detection as well as imprinting.

[0022] Figure 6 shows an imprinting mold with monitoring marks in accordance with the present invention. As shown in figure 6, a mold 610 comprises at least one monitoring mark 611 for monitoring mold deformation. The monitoring marks are placed at any location on the mold 610.

[0023] While we have shown and described the embodiment in accordance with the present invention, it should be clear to those skilled in the art that further embodiments may be made without departing from the scope of the present invention.